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DEPARTMENT OF PSYCHOLOGY
The University of Michigan, Ann Arbor

Spatial Effects in Visual Selective Attention

INGE F. BENNETT

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13. ABSTRACT

In many visual selection experiments, Ss view displays of colored letters and numbers. They are instructed to attend to some stimulus dimension (e.g., row location, color class) and are cued to report the items indicated by one value (e.g., top row, red color) on that dimension. Accuracy is always highest for row report. Since the items cued by row are spatially connected and easily coded for memory, and those cued by color or class spatially scattered and difficult to code, it cannot be concluded that row selection is more efficient than, say, color selection.

In these experiments, selection criterion is held constant, and the spatial arrangement of the targets is varied. In Exp. I, Ss reported the identities of the 5 red letters appearing in a 5 x 5 matrix. Four types of target arrangements were tested. Four backgrounds, varying in degree of confusability with the targets, were combined factorially with the four target patterns. The effects of pattern and background and their interaction were highly significant. It is suggested that spatial arrangement *per se* is not crucial; rather the target pattern serves to control the degree of background interference.

Experiments II and III were detection analogs of the Letters background similarity condition of Exp.I. The Ss had to report whether an A or a T appeared among the red letters. The results for the pattern types were similar, indicating that there are spatial constraints on visual processing at a level low enough to be tapped in a detection task.

Two models of tachistoscopic perception, the Rumelhart (1970) and the Gardner (1970) models, were discussed. Neither can handle the results of the current experiments without extensive modification.

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THE UNIVERSITY OF MICHIGAN

COLLEGE OF LITERATURE, SCIENCE AND THE ARTS

DEPARTMENT OF PSYCHOLOGY

SPATIAL EFFECTS IN VISUAL SELECTIVE ATTENTION

Inge Fryklund Bennett

HUMAN PERFORMANCE CENTER--TECHNICAL REPORT NO. 32

August, 1971

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PREFACE

This report is an independent contribution to the program of research of the Human Performance Center, Department of Psychology, on human information processing and retrieval, supported by the Advanced Research Projects Agency, Behavioral Sciences, Command and Control Research under Order No. 461, Amendments 3 and 5, and monitored by the Behavioral Sciences Division, Air Force Office of Scientific Research, under Contract No. AF 49(638)-1786.

This report was also a dissertation submitted by the author in partial fulfillment of the degree of Doctor of Philosophy (Psychology) in The University of Michigan, 1971. The doctoral dissertation committee was: Drs. R.W. Pew, Chariman, R.A. Bjork, W.R. Kincaid, and R.G. Pachella.

TABLE OF CONTENTS

ABSTRACT

In many selection experiments, comparisons have been made between a condition in which a row is cued, and various conditions in which attributes such as color, size or class serve as the selection criterion. In the latter conditions, the target items are scattered randomly throughout the display. Row report has always been the most successful, but since selection criterion and target-set configuration are confounded, it is inappropriate to conclude that row selection is more efficient that, say, color selection.

Experiment I was designed to unconfound selection criterion and target-set arrangement, and to investigate some of the properties of different arrangements that might be responsible for performance differences. In a 5 x 5 matrix, five positions contained red letters, and S was instructed to report only these letters. The color, in effect, served as a simultaneous cue directing attention to particular positions. Two characteristics of the target configuration, connectedness and codability, were varied. Two levels of each were combined factorially to yield four target pattern conditions: rows, arbitrarily chosen patches, spread-out symmetric designs, and random scatters. In addition, target-background similarity was varied since it is possible that any spatial effects in previous experiments are specific to the highly similar backgrounds used and not to target-set patter *per se*. Four backgrounds (Black letters, black numbers, open black squares, or blank) were combined factorially with the four target-set patterns to yield 16 selection conditions.

The main effect of Pattern was highly significant; performance was best in the row condition and much worse on all other patterns. Background was also very important; performance was best in the blank background condition and decreased systematically with increasing target-background similarity. There was also a strong interaction between Pattern and Background; when no background items were present, there was little effect of Pattern, and when targets were in a row, the nature of the Background was relatively unimportant. Clearly, much of the row-color difference found in previous experiments is due to spatial effects alone. Since performance was high and relatively invariant with Pattern in the blank background condition, it is suggested that target pattern *per se* is not crucial; rather the pattern serves to control the amount of interference from the background.

The row pattern may be superior because of short-term memory coding advantages: The row pattern is easily described, and a row tag plus an ordered list of elements allows S to pair positions and elements accurately. The other three patterns are more difficult to

describe, and there are no simple pairing rules. Experiments II and III, detection analogs of Experiment I, were designed to test this possibility. The S had to determine whether an A or a T appeared among the five red letters in the 25-letter display; no use of short-term memory is required. For Ss who were able to distinguish the red color, row was clearly superior to the other patterns. A comparison between all pattern conditions combined and a whole-matrix control indicated that practiced Ss were making some use of all patterns. Thus, while memory coding differences may be involved in the spatial effects found in Partial Report, most effects of target-set arrangement reflect processes low enough to be involved in Detection. The substantial row advantage probably reflects scanning habits acquired through reading practice.

Two models of tachistoscopic perception, the Rumelhart (1970) multicomponent model and the Gardner (1970) Independent Channels-Confusions model, were discussed. It appears that neither can handle the results of these experiments without extensive modification.

CHAPTER I

INTRODUCTION

When presented with a tachistoscopic array of letters and/or numbers, subjects typically report no more than 4 or 5 items, yet insist that thev were able to "see" a much larger portion of the display. During the time taken to identify and emit these items, the rest of the display appears to fade away. The number of items reported is in accord with the typical findings of a memory span experiment. Even when a subject has ample time to perceive a set of visually or auditorily presented items, he rarely reports more than 5 or 6 accurately. This number is increased only when additional time is provided for rehearsal and recoding for memory. Thus, performance in the tachistoscopic task must at least in part reflect verbal memory limits. Because of this limit it is impossible to determine the number of items initially available, the degree to which they are processed, or what becomes of them, by asking S to report all of the display. Instead, some method must be used that avoids confounding perceptual capacities with memory loss and confusion.

The Partial Report Paradigm and the Problem of Selection

Sperling (1960) introduced such a method. He developed a sampling or partial report procedure in which a post-stimulus cue directed S to report only the items in a single row of the display. Since S did not know which row was to be cued and thus had to be prepared to report any row, the average proportion of cued items reported was taken as an estimate of the proportion of the whole display available to S at the time of his perception of the cue. In experiments in which the post-stimulus cue delay was varied, the partial report estimate declined systematically from an immediate post-cue value of 75% to 80% of a 12 or 16 item display until it reached the whole report level after a delay of about 300 msec. These estimates of 9 or 12 items available are considerably in excess of the whole report level of 4 or 5.

These cueing results were given the following interpretation by Sperling: The sizeable whole-partial difference indicates that most of the items in a display are registered in some large capacity store from which S can select one memory span's worth of these available items for output. The precipitous drop in the availability estimate with increasing cue delay indicates that the contents of the store decay rapidly (The finding that the partial report estimate did not fall below the whole report level even at very long delays suggests that S had adopted the strategy of reading out some items prior to the cue; in experiments in which S is urged to avoid early read-out, performance drops to a near chance level). Since the decay functions are strongly influenced by such stimulus parameters as the brightness of the stimulus and of the pre- and post-stimulus fields, and since errors are more often visual than acoustic confusions, the store was considered to be visual in nature. Accordingly, Sperling termed it the Visual Information Store (VIS). It has also been referred to as the visual memory, sensory register, and short-term visual store. All terms connote a transient, visual and pre-verbal store.

Sperling's experiment was useful for providing some direct evidence for the existence of the visual memory that common observation (of afterimages, for example) had long suggested. The cueing procedure also provided a method for measuring the capacity of this store. Most important, however, was Sperling's demonstration that selective read-out from the store was possible: Subjects appeared to have independent access to the stored items; at least, Ss could access one row as readily as another.

The problems of selective readout from the store and the existence of the large capacity store are thus very closely bound together. First, the existence of the VIS can be inferred only from a successful selection experiment; operationally, the whole-partial difference permits the inference of large capacity. Thus, in order to claim evidence for the VIS it is necessary to demonstrate a reliable whole-partial difference free of any artifacts of scoring method, subject strategy or non-perceptual memory confounding. In addition, the particular measure of availability obtained in a partial report experiment must be specific to the selection criterion used; e.g., if S is less adept at accessing columns in a display matrix, the availability estimate obtained with column cueing should be lower.

Second, since selection is presumably possible only because of directed access to the visual trace, performance in selection experiments should reflect properties of the store, the degree to which items in it are processed, and something about S's control processes. These properties and processes must be considered in any model of visual perception. To take only one example, a model of the VIS as a pictorial, 2-D representation which S can view as he can any picture is consistent with the finding of row selection. A finding that not all spatial patterns were as readily accessed might call this model into question. It might be modified by adding assumptions about the difficulty of locating different spatial subsets, or be replaced by some list model in which items are labeled and can be located by only some tags, such as row or column labels.

Experimental Approaches to Selection and the Visual Store

It is thus clear that investigations of the visual store and of the extraction of registered items for later processing, memory storage or output must focus on questions of selectivity. Since the late sixties, a number of such studies have been carried out. Three distinct experimental-theoretical approaches have been taken in these studies. First, several investigators (Clark, 1969; Dick, 1969, 1970; Von Wright, 1968, 1970) accepted the existence of the visual store and concentrated on rank-ordering the efficiency (i.e., the size of the whole-partial difference) of various selection criteria. Some experiments ordered the criteria at a single cue delay; others attempted to map out cue delay functions for each of the criteria. These experiments, which provided basic data about selection effects, will be considered further below.

Two other approaches took a more critical view of the VIS and investigated possible artifacts in the whole-partial difference. Holding (1970) investigated eye fixation artifacts in row selection. He reasoned that if S could predict which row would be cued and if he fixated it, he could have an elevated partial score even if he never had available more than a single row. Holding constructed stimulus sequences with varying degrees of predictability and found that performance varied systematically with predictability. He concluded that postulation of a visual store was thus unnecessary. It would be more appropriate to conclude that care must be taken in the construction of stimulus sequences when spatial attributes are cued. Since fixation strategies are not possible with non-spatial information, and since whole-partial differences can be obtained with such criteria, Holding has scarcely proven that a visual store is not required. He has, indeed, only demonstrated that it is possible to devise a visual task in which selection is not required.

Holding (1970) and Dick (1971) have taken a third approach. They have discussed possible scoring procedure artifacts which might have produced whole-partial differences in the absence of any ability to select from a visual store. Holding pointed out that whole report typically requires the output of 4 or more items, while partial report cues a subset of 4 or fewer. Thus output interference is more likely to depress the whole report score, artificially inflating the whole-partial difference. Dick elaborated this position. Since overall accuracy should be a function of the number of items emitted, he concluded that it was inappropriate to compare the proportion of the whole display given in whole report with the proportion of the smaller subset reported in partial report; the proportionality measure was biased against whole report. In order to equate output interference, he scored only the first 4 responses in both whole and partial report for an experiment in which the partial estimate exceeded the whole report level according to the usual scoring procedure. He then examined the probability of a correct response as a function of its ordinal position in output. Dick found that accuracy decreased monotonically with output position and that whole report accuracy was higher for all output positions. He concluded that "Because of the failure to find [absolute] superiority of partial report over full report, there is no need to postulate a mechanism of selectivity in visual memory (1971, p. 262)." By inference, he is also denying the evidence for a large capacity visual store.

While Dick has raised some valid points about the appropriateness of the whole-partial comparison, his conclusion about selection is hardly justified. A difference between the absolute levels of whole and partial report cannot be used to support an argument against selection, because the observed ordering is the only one that could have occurred. Presumably, in whole report, S reports the items that are clearest, perhaps those in the top row or nearest the fovea. In partial report, the experimenter's preference and not his own governs S's choice of items for output. The cued positions are usually balanced over trials so that all display positions are sampled. Thus, the partial score reflects performance on both clear and unclear items, and so must be lower. Such results can also be obtained in non-visual experiments. For example, if S learns a list of words, he is more accurate if he reports only those that he wishes (free recall) than if he is constrained to report a particular portion of the list (Slamecka, 1969). Further, assuming that S can select from a visual trace, he may begin readout of "correct" items immediately with whole report, but must delay with partial. It takes time to process a cue and redirect attention, so S must read from an older trace. Of course, performance must be lower. The absolute levels of performance in whole and partial report could coincide only if the experimenter's and the subject's element preferences agreed, and if the cue and display were simultaneous and the cue processed instantaneously. Dick's Fig. 1a, in which absolute accuracy for top row, bottom row, and whole report are plotted, supports this interpretation. The curves for whole and top are closer together than those for bottom and top. The distance between the whole and partial curves could, indeed, itself be used as an index of selection efficiency.

The current paper considers a fourth approach to the selection problem: What are the precise task demands, in terms of spatial and item uncertainty, of any particular partial report experiment? In a selection experiment, the items to be reported may be specified by any of their attributes, for example, row location, color, or class membership. The size of the whole-partial difference should vary with the criterion chosen, but it is not safe to conclude that performance differences reflect only the differences in processing the different attributes.

Items specified by any criterion must appear in specific positions. The S must attend to these positions in order to read the cued items, and may have to report the positions along with item identity. If different criteria are associated with different spatial arrangements of the cued subset, it cannot be concluded that experimental effects reflect attribute processing differences alone, since there may be differences due to the varying spatial processing demands. Item uncertainty refers to the number of potential responses. For example, consider a display matrix composed of a random mixture of 6 letters, chosen from a population of all 26, and 6 numbers chosen from the 10 possible. If S must report those elements in a particular row, he has 36 elements to consider when identifying the cued items and must remember which of the 36 are appropriate when it is time for output. If S is cued to report only the letters or only the numbers, item uncertainty is lower, 26 or 10 items respectively. Clearly, because of the differences in item uncertainty, it is not possible to compare row and category report and conclude unambiguously that row processing is (or is not) easier than category processing.

Questions about task demands are of interest in their own right for providing finer grained analyses of selective access, and are also crucial for evaluating earlier work comparing selection criteria. Performance in the partial report task cannot be modeled until the relative contributions of attribute processing, spatial limitations, item uncertainty, memory requirements, etc. are understood. In the remainder of this paper, published literature on selection efficiency will be reviewed in the light of spatial and item uncertainty, and some direct tests of the spatial effects will be reported.

Review of Selection Literature

Sperling demonstrated row selection but found that a semantic dimension could not be used. He displayed matrices of mixed letters and numbers (Exp. VI) and cued Ss to report only the elements of one class or the other. The partial estimate did not exceed the whole report level even when the cue was given well in advance of the stimulus. After this failure, the matter of selection criteria received little attention until von Wright (1968) tested some additional criteria. In matrix displays, 2 values of some dimension were represented, and Ss were cued to report the letters identified by one value. The dimensions used were row, color, size, brightness, and orientation (0° vs. 45° and -45° vs. +45°). Row was found to be most successful, with color, size and brightness successively less so. No whole-partial difference was found in the 2 orientation conditions.

The results are consistent with the hypothesis that selection is possible only when S is able to reject some items on the basis of low level tests, and then to devote most of his processing capacity to identifying the "correct" ones. Von Wright suggested that such "screening" is not possible in the orientation conditions because S must determine letter identity before he can decide whether the letter is properly oriented. Of course, both the absolute level of performance and the relative ordering of the selection conditions depend on the difficulty of the discrimination between the 2 values of each dimension.

Row report is superior to the other conditions, but because of confoundings with spatial uncertainty, this does not necessarily mean that the attribute of row location is more easily determined that of color or size. The elements in a row subset are spatially connected; in all other conditions the subsets are spatially scattered.

In addition, the row sample is one of only 2 or 3 possible and, in the course of the experiment, S has a great deal of practice in attending to any one. In the scattered conditions, there are many different potential samples (i.e., the number of ways that r cued items might be selected from N display elements), and S has little practice in attending to any one. There may be corresponding difficulties when S attempts to code for verbal memory the positions of the items he has identified. The term "spatial uncertainty" should be understood as shorthand for all of these aspects of spatial processing. Thus, comparisons among the scattered conditions are clean, while comparisons between any of these and the row condition may reflect attribute processing differences and/or any of the factors involved in the spatial differences.

Von Wright (1970) tested 3 new conditions: Letters vs. numbers (L-N), consonants vs. vowels (C-V), and normal vs. mirror images. The partial report estimate for L-N exceed whole report only for 2 practiced Ss (out of 10), and only one of these Ss could discriminate C-V. No S was able to select on the basis of normal vs. mirror. These conditions are similar to the orientation condition in that class membership cannot be established before item identity. In terms of spatial uncertainty, these conditions are identical to all of the scattered conditions in the previous experiments. This experiment, however, introduces item uncertainty. In the L-N and C-V conditions, the cue serves to limit the number of elements that S need match or remember. In addition, there are quantitative differences between L-N and C-V in the degree of reduction in item uncertainty.

Dick (1969) presented 8-element arrays in which half the elements were red and half black, and half letters and half numbers. Partial report of L-N was most successful, with row report being more difficult, and color worst of all. (This ordering was replicated by Dick, 1970). The ordering (although nonsignificant) is consistent, and is rather puzzling until the task demands of spatial and item uncertainty are considered. L-N has high spatial uncertainty, but low item uncertainty; the letters and numbers were each drawn from populations of 8, so the cue halves the number of potential responses. Given this small stimulus population and the free recall scoring, it is possible that most of the observed L-N effect was due to guessing. Row report has high item uncertainty, but low spatial. Color has high demands on both factors. The observed ordering is roughly that predicted by the uncertainties alone, assuming that low item uncertainty is here more beneficial than low spatial uncertainty.

Clark (1969) presented arrays of colored circles. In row report, S was to report the colors, in correct position, of the circles in the cued row. For color report, he was to check off the positions occupied by the circles of the cued color. Row selection was found to produce higher recall. This result makes sense in terms of attribute processing alone, but is also predictable from the task uncertainties. The differences in codability are particularly striking. Color selection required location of scattered positions and memory for the correct 5 out of 15. In row report attention may be directed to a single row, and S need remember only an ordered list of 5 colors plus a row "tag".

An experiment by Turvey and Kravetz (1970) was very similar in conception. Equal numbers of R's, O's and A's were displayed and partial report was cued by row and letter. The task uncertainties are qualitatively similar to those of the Clark experiment, and the results can be similarly predicted. Row report was considerably better. The authors, however, recognize the possibility of task demand confounding, and suggest that the superiority of row report may be partially explained by assuming that location uncertainty is more detrimental in the letter condition than item uncertainty is in the row condition.

It is now evident that spatial and item uncertainty are extremely powerful determinants of performance. In some experiments they are strong enough to override the effects of the selection criterion *per se*; in others they simply preclude the possibility of obtaining clean direct comparisons between selection conditions. It is thus obvious that the current "scattered attributes plus cue" design is inadequate for investigating selective access to the visual trace. Item uncertainty might be investigated by a parametric study of stimulus population size. A new method must be devised for a direct test of spatial effects. Such a method is introduced in the next chapter.

CHAPTER II

EXPERIMENT I

Introduction

This experiment was designed to provide data pertinent to two sets of questions about spatial constraints on performance in a visual selection task. The first questions are empirical: How is performance influenced by the spatial arrangement of the elements in a cued subset? How large are these effects relative to the effects of selection criteria? What are the properties or characteristics of the subset configurations that determine the observed effects? The second questions are more theoretical: Why does the spatial arrangement matter; i.e., what processes in selective attention are constrained by spatial factors?

The first set of questions are investigated by holding the selection criterion constant while systematically varying the spatial arrangement of the cued elements Five positions in a 5 x 5 matrix are filled with red letters and S is instructed to report their identities and positions. Color, in effect, is serving as a simultaneous cue directing attention to particular positions in the matrix. Any observed variation in performance must be attributable to spatial configuration.

In the preceding chapter it was noted that spatial uncertainty is shorthand for a number of factors that might be responsible for the spatial effects. This experiment focuses on 2 of them, connectedness and codability. Two levels of each are combined factorially to yield 4 distinct spatial pattern types: connected and readily coded (exemplified by a row pattern), connected but less easily coded (exemplified by spatially adjacent but arbitrarily selected sets of 5 elements), unconnected-codable (spatially separated elements forming a right-left symmetric design), and unconnected-uncodable (randomly scattered elements). Previous experiments (which have also confounded selection criterion and spatial arrangement) have tested only the first and last class.

The second set of questions are investigated by considering more closely exactly what S must do in a selection task. Each display is composed of 2 components, the target elements and the background elements. The S must attend to the former and ignore the latter. Thus performance must be determined by his performance on these 2 complementary tasks. The effects of experimental variables which affect Ss ability to attend and ignore should provide some clues about how selection is accomplished.

The roles of pattern and background are investigated in Experiment I by incorporating variation in the similarity of cued and background items as well as variation in the spatial arrangement of the cued elements. Four levels of target-nontarget confusability are tested. These are combined factorially with the 4 pattern types to yield 16 selection conditions. This design permits the assessment of main effects of pattern and background and any interaction between them.

Method

Subjects--The subjects were 4 men and 4 women students at the University of Michigan who volunteered to serve as paid Ss. Each S was paid $5.50 for participating.

Stimulus Materials--The stimulus elements for each item were positioned in 5 x 5 arrays centered on white 4 x 6 notecards. In each array, exactly 5 of the positions were filled with red letters. The patterns formed by the red letters (Fig. 1) represented the following types: I-connected/codable, II-connected/arbitrary, III-unconnected/codable, and IV-unconnected/arbitrary. For each pattern type, 5 exemplars were constructed. These were chosen to be perfectly interlocking; over 5 exemplars, each containing 5 red letters, each of the 25 matrix positions were filled exactly once with a red letter.

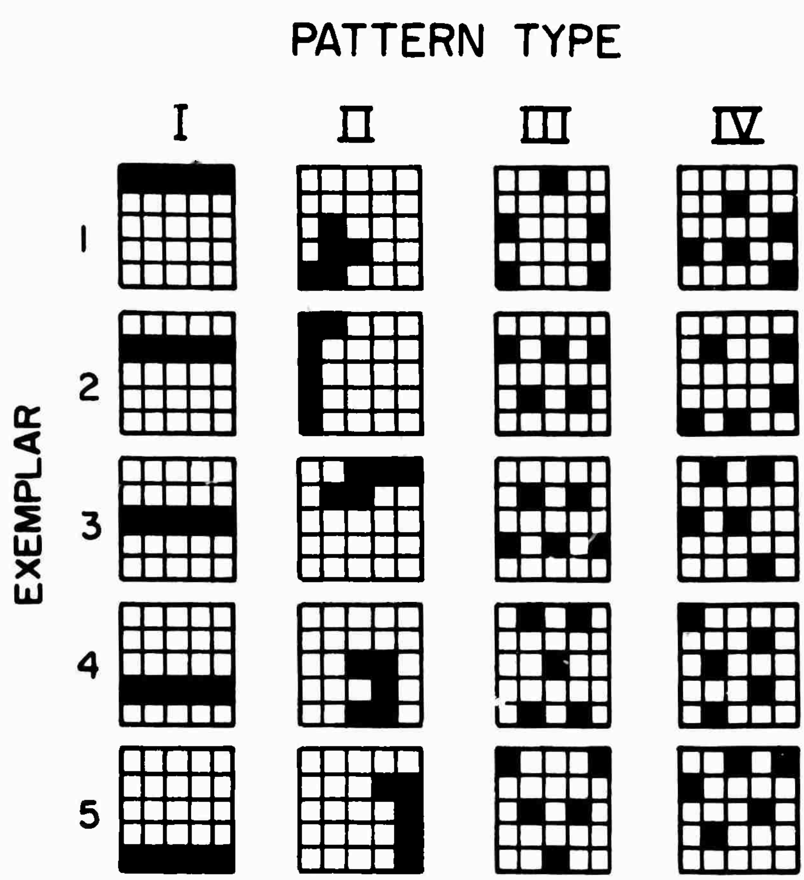

Fig. 1. The four pattern types and the five exemplars of each used in Experiment I.

The 5 exemplars of each pattern class were also chosen to meet the criterion of being good representatives of their type. Pattern goodness for the unconnected pattern types was established by constructing 3 codable and 2 arbitrary sets of 5 exemplars each. The 25 patterns were then presented in random order to 8 Ss who sorted them into 2 piles, one for structured and one for random patterns. The Ss were then asked to subdivide these piles into any desired number of categories according to the obviousness of the design or the degree of randomness. Pattern goodness for the connected/arbitrary category was defined as variety in the shapes and orientations of the groupings of the red letters.

In addition, the two unconnected sets and the two connected sets were chosen to be similar in their spatial dispersion over the matrix. The dispersion measure used was the sum of the squared deviations of the red positions from their centroid. The average dispersions for patterns III and IV were 19.37 and 18.08 respectively. The row pattern (I) has the maximum dispersion possible for a set of 5 connected items (10.00). All other connected patterns (i.e., those chosen for pattern type II) must have smaller dispersions. The exemplars chosen for type II are "good" patterns with a relatively large average dispersion (6.32). It should be noted that both the connected and unconnected sets are biased against the hypothesis that structure or codability helps. The spatial dispersion of the codable sets is greater than that of the corresponding arbitrary set. Because of the requirement of pattern interlocking, each of the 4 pattern types has the same average centroid (the fixation point) and average squared deviation from the fixation point (20.00). Appendix I gives the centroid, deviation from centroid, and deviation from the fixation point for each exemplar of each pattern type.

Each exemplar was paired with 4 background types which varied in degree of confusability with the red letters. They were black letters, black numbers, open black squares, and empty spaces. Thus, a total of 4 patterns x 5 exemplars x 4 backgrounds or 80 distinct item designs were constructed. Each design was filled with 2 samples of target items to make a total of 160 stimulus items. (For the Letters and Numbers background items, 2 sets of background items were also used.) Four of the 160 items, illustrating the 4 pattern types and 4 backgrounds, are shown in Fig. 2.

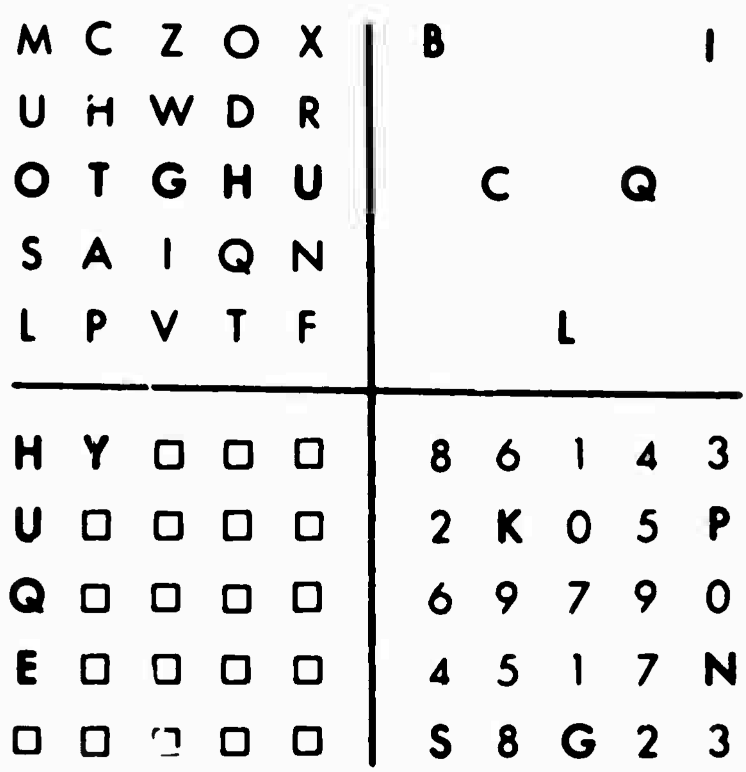

Fig. 2. Four of the 160 stimulus arrays, illustrating the four pattern types and four backgrounds, suded in Experiment I. Arrays are shown actual size; at 117 cm.viewing distance, their dimensions are 2° x 2°.

For each stimulus card, 5 letters for the 5 red target positions were chosen randomly without replacement from the population of all 26. Over all 160 items, each letter was used in a red position a total of 30 or 31 times, and in each matrix position at least once but not more than twice. Over all 40 items requiring letter backgrounds, each of the 26 letters was used 30 or 31 times, and at least once but not more than twice in each matrix position. No letter was repeated among the background 20, but since target and background letters were chosen independently, there were some cases in which 1 or more letters appeared in both target and background. Letter arrangements forming words or common abbreviations either horizontally or vertically were avoided. For the 40 number items, the digits 0-9 were assigned randomly to the matrix positions with the constraint that each appear twice in each array. Over the 40 items, each digit appeared 3 or 4 times in each matrix position.

All letters and numbers were in Futura Medium 18 pt. type, with the background elements made with Prestype #1280 and the red letters with Tactype #5518 rub-off lettering. Although the two brands are highly similar, they are not identical; the red letters had somewhat thicker strokes. Thus size and perhaps light-dark ratio were correlated with color and may have served as additional cues for locating the target positions. The open squares were Paratipe #55008, 1/8". The stimulus arrays formed a square 4 cm on a side (2° at 117 cm viewing distance). The side-to-side and top-bottom distance between the centers of the elements was 9 mm (.45°). Three coats of Krylon Crystal Clear plastic spray were used to fix the elements.

Apparatus--Stimulus cards were presented in Field 1 and a grey fixation dot in Field B of a Scientific Prototype 3-channel tachistoscope. Since the lighted areas in the fields are rectangular, square masks were used to frame the arrays. Luminances in the 1 and B fields were approximately 18 and 8 ft.—Lamberts respectively. Field B was illuminated throughout the session except during the 30 msec stimulus exposures. The room was dark except for the experimenter's light which was shielded from the subject, and a 25-watt bulb was positioned to provide just enough light to enable S to write his answers. The subject initiated stimulus presentations by means of a handswitch. Responses for each session were written in 8 booklets of 20 pages each. The Unaided recall condition used single pages, each with a 5 x 5 matrix of dashes representing matrix positions. Aided recall used the same matrixes with the addition of 5 boxes indicating the positions of the target elements. Pages were folded double thickness to prevent viewing of the following page.

Procedure--Each S was tested in 3 sessions spaced approximately 24 hours apart. Day 1 was practice, and Days 2 and 3 the experimental sessions. The 160 items were arranged in a single random order, and 4 presentation conditions were defined by the factorial combination of forward or backward order of the deck and Aided or Unaided recall. For the first experimental day, each pair of Ss (1 male and 1 female) was assigned to one of these 4 conditions. On Day 3, each S was tested on the opposite stimulus order and the other recall condition. On Day 1 (practice) each S was tested on his

Day 3 stimulus order, with the first 80 items having the recall condition of Day 3 and the last 80 the recall condition of Day 2. Subjects tested on Aided recall on Day 2 and Unaided on Day 3 will be referred to as Group 1; those tested on the reverse sequence are Group 2.

On Day 1 the *Ss* were shown 5 cards illustrating the 4 pattern types and 4 backgrounds. The 5 row by 5 column structure of each item (including that of the items with randomly arranged targets and Blank backgrounds) was pointed out. The subjects were told that exactly 5 of the positions, forming "rows, patches, spread-out patterns or random scatters", would be filled with red letters. They were instructed to ignore the background elements and report the red letters, guessing if they had any idea at all about the identities of the red letters, and specifying position whenever possible. They were also told that the various combinations of pattern and background would be scattered throughout the session and that there was no significance, other than convenience of stapling the pages, to the division into 8 booklets. For Aided recall, the *S* was asked to grasp the corner of the next page, to turn it only after stimulus presentation, and to be very careful not to look ahead; *Ss* were observed to follow these instructions. For Unaided recall, they were told to turn the page before or after stimulus presentation as they pleased. The trials were self-paced, and session duration ranged from 25 to 45 minutes for different subjects. A break was permitted half way through each session, but was rarely taken. The 5 demonstration cards were used as warm-up at the beginning of each session. At the end of Day 3 the last 4 Ss were tested for their memory of the configurations of the red letters. They were given sheets of paper filled with matrixes as in the Unaided recall condition, and were asked to reproduce the patterns they had seen.

Results

The subjects' written protocols were scored using two criteria, one lenient (free recall) and one strict (letters in correct position). For the Unaided condition, the free recall score is the number of target letters reported regardless of their placement among the 25 matrix positions, and the position score is the number placed in the positions in which they were presented. For Aided Recall, free recall and position scoring refer to placement within the 5 boxes provided at recall. Because the probability of a correct position assignment by guessing alone is higher in the Aided condition, the position measure is not comparable for the two recall conditions. In addition, Ss' comments indicated that Aided Recall constrained guessing (and thus the free recall score) as well; S might identify a letter which he thought to be red, but would refrain from writing it if no box were provided in that position. For Unaided Recall, there was no similar check, and S might report the identities of black letters. Since in some cases a letter appeared in both the cued set and the background, unchecked guessing might have elevated the lenient score for Unaided Recall. For these reasons, Free and Position scoring have slightly different meanings in the two Recall conditions. Thus the 2 conditions cannot be compared directly, and are treated separately in all the analyses reported below.

The main results appear in Figure 3. The Mean number of cued letters reported is shown as a function of Pattern and Background, and data for the 2 Recall conditions are averaged over Order of Presentation. It is very clear from this Figure that variations in Pattern and Background have strong effects on performance, and that Pattern and Background interact. These observations are confirmed by the statistical analyses. Four separate 3-way analyses of variance (Patterns (4) x Backgrounds (4) x Order of Recall conditions (2)) were performed, one for each Recall condition under each scoring method. All the results reported below are based on these analyses.

Effects of Order of Recall Condition--Subjects who were tested on Aided Recall on their first experimental day (Group 1) had somewhat higher overall performance, but the main effect of Order was significant only for the Unaided/Free analysis ($F_{1,6} = 6.2148$, $p < .05$). For Aided Recall, Order did not interact with Pattern, Background, or the Pattern x Background interaction. For Aided/Free the Pattern x Order interaction was highly significant ($F_{3,18} = 10.6294$, $p < .001$), while the triple interaction was marginally significant ($F_{9,54} = 2.0624$, $p < .05$). Under Position scoring, the Pattern x Order interaction was marginally significant ($F_{3,18} = 4.9957$, $p < .05$). The interaction with Pattern reflects only the fact that Group 2 Ss were relatively poor at using all patterns on their first experimental day; after Day 2 practice with Aided Recall, the Group 1 Ss were relatively more skilled at using the connected patterns. Since these interactions reflect only an anticipated practice effect, and do not involve either the Background effect or

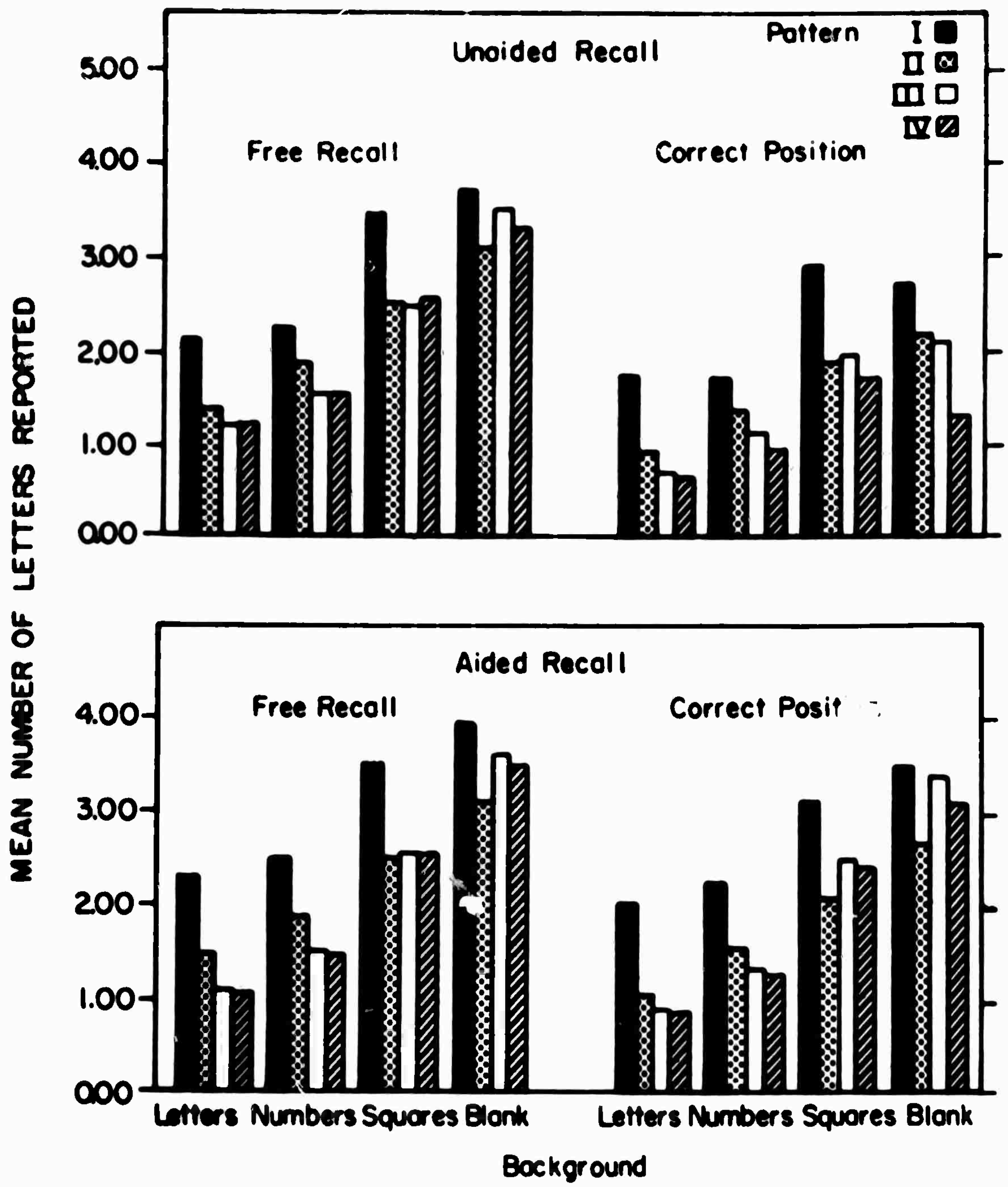

Fig. 3. Mean number of cued letters reported (five maximum) as a function of pattern and background for two types of recall and two scoring methods.

the Pattern x Background interaction, the Order variable will not be considered further.

Main Effects of Pattern and Background--The effect of Pattern was found to be highly ($p < .001$) significant (Unaided/Free, $F_{3,18}$ = 64.9005; Unaided/Position, $F_{3,18}$ = 33.0800; Aided/Free, $F_{3,18}$ = 73.0575; Aided/Position, $F_{3,18}$ = 63.3184). The effect of Background was also highly ($p < .001$) significant; the F ratios (df = 3,18) with the scoring and recall condition analyses in the same order are: 111.2863, 27.7765, 155.4467, and 273.2803. The summary tables on which this and all succeeding analyses are based may be found in Appendix II.

Most of the Pattern effect appears to be due to the row (Pattern I) cueing condition. Performance is lower in the other conditions, and their ordering varies. To assess the relative contributions of the different patterns, the Pattern main effect was partitioned into 3 orthogonal comparisons. These results are shown in Table 1. The superiority of the row pattern is unquestionable. The I vs. (II, III, IV) comparison accounts for 85% to 99% of the Pattern sums of squares.

TABLE 1

F RATIOS FOR PATTERN MAIN EFFECT MARGINAL COMPARISONS

Comparison	Unaided		Aided	
	Free Recall	Correct Position	Free Recall	Correct Position
I vs. (II, III, IV)	193.382***	84.6910***	217.5875***	181.6469***
II vs. (III, IV)	1.071	7.8238**	1.1887	7.5333**
III vs.IV	.2480	7.0490**	.3962	.7750

***p < .001 **p < .01 df = (1,18)

In contrast to the finding that the Pattern main effect is primarily due to a single pattern condition, there appear to be large and consistent differences among all 4 Background conditions. The Background effect was also partitioned into 3 orthogonal comparisons. These analyses are shown in Table 2.

TABLE 2

F RATIOS FOR BACKGROUND MAIN EFFECT MARGINAL COMPARISONS

Comparison	Unaided		Aided	
	Free Recall	Correct Position	Free Recall	Correct Position
B vs. (SLN)	210.1940***	26.4851***	303.0030***	446.5356***
S vs. (LN)	113.9038***	52.9701***	150.8696***	241.0042***
L vs. N	9.7612**	3.8744	12.4675***	24.3013***

***p < .001 **p < .01 df = (1,18)

For all analyses except Unaided/Position, the results for the first 2 comparisons are highly consistent. The Blank vs. filled background comparison accounts for the majority of the Background effect. Clearly it is easiest to process the target elements when there are no interfering background elements. The Squares vs. Letters and Numbers comparison is highly significant; roughly 1/3 of the Background sum of squares is accounted for by this comparison. The source of this effect is ambiguous, since 2 factors are confounded. First, the Squares background is honogeneous while the Letters and Numbers backgrounds are heterogeneous; it may be easier to distinguish figure and ground when the background elements have a constant value and only the targets vary. Second, the Squares share relatively few features with the targets, while the Letters and Numbers share many; even if S has difficulty attending to the targets alone, he may not be confused by the Squares. A condition in which heterogeneous yet non-confusable items (e.g., assorted geometric shapes) fill the background positions should separate these similarity and homogeneity factors. In any case, the finding that both of these comparisons are highly significant, with the first accounting for more of the total variance, indicates that the Blank and Square conditions differ. The Squares condition was included as a control for the retinal interaction (simultaneous masking) which, along with feature similarity, must be involved in the Letters and Numbers conditions. Evidently, it is detrimental to have any dark objects in the field.

In the Unaided/Position analysis, about 2/3 of the background sum of squares is due to the Squares vs. Letters and Numbers comparison, and about 1/3 to the Blank vs. filled comparison. This reversal reflects a complete absence of a difference in the marginal totals for the Squares and Blank conditions. In the other 3 analyses, the Blank condition has an advantage because there is nothing to interfere with the perception of the red letters (except some masking of the red letters by one another). However, the absence of any background makes it difficult for S to determine the absolute spatial coordinates of the red elements. Since this loss of position information is not critical in Aided Recall or for Free recall scoring of Unaided recall, it appears only in the Unaided/Position analysis. The processing advantage and the position disadvantage seem to have averaged out to a fortuitous zero difference.

The Letters-Numbers comparison accounts for the least part of the Background effect under all 4 analyses. The differences among the F ratios are probably too small to warrant attempts at explanation.

Pattern x Background Interaction--It is apparent from Fig. 3 that the Pattern effect varies with level of Background, the ordering of the patterns being systematic with the Letters background, and relatively unsystematic with the Blank background. Conversely, the nature of the Backgrou ! is most important with the random pattern, and least with row. This interaction between Pattern and Background was highly significant ($p < .001$) for all analyses except Unaided/ Position ($p < .05$). The interaction can be viewed from either of 2 points of view, the Pattern effect varying with level of Background, or *vice versa*. Thus the data were analyzed in terms of the simple main effect of each factor at each level of the other factor. In addition, each simple main effect was partitioned into 3 orthogonal components. These analyses are shown in Tables 3 (Pattern simple effects) and 4 (Background simple effects).

To summarize the effect of Pattern shown in Table 3, the row pattern accounts for most of the Pattern effect when Letters, Numbers and Squares appear in the background. This finding indicates that when target and background items are similar, *S* is most likely to avoid confusing them when the targets are grouped in a row. However the row advantage is still highly significant with the Blank background (although it is no longer so clearly superior to the other pattern conditions); this suggests that the row is more easily perceived and is less subject to interference.

TABLE 3

SIMPLE MAIN EFFECTS AND ORTHOGONAL CELL COMPARISONS:

F RATIOS FOR PATTERN AT EACH LEVEL OF BACKGROUND

Level of Background	Unaided Free Recall	Unaided Correct Position	Aided Free Recall	Aided Correct Position
Letters	27.0255***	19.0422***	30.2905***	18.6608***
I(II,III,IV)	74.9675***	53.3425***	80.7515***	54.7133***
II(III,IV)	6.1008*	3.7002	10.0939**	1.2498
III,IV	.0021	.0839	.0262	.0191
Numbers	9.6152***	5.9621	21.5619***	11.8633***
I(II,III,IV)	24.4267***	14.5498***	57.2379***	32.5232***
II(III,IV)	4.4189*	5.0991*	7.3434**	2.9475
III,IV	.0000	.7554	.1047	.1195
Squares	23.5802***	18.7973***	22.0782***	12.3065***
I(II,III,IV)	70.5307***	53.3424***	66.0515***	30.6198***
II(III,IV)	.0027	.0279	.1768	6.1277*
III,IV	.2071	3.0217	.0065	.1722
Blank	7.0923**	20.3292***	8.6400***	9.5035***
I(II,III,IV)	11.6879**	34.6247***	14.1848***	6.4561*
II(III,IV)	7.4679**	9.3187**	11.3163**	21.8218***
III,IV	2.1211	17.0443***	.4191	.2343

Simple Main Effects df = (3,54) cell comparisons df = (1,54)
***p < .001 **p < .01 *p < .05

Pattern II has a small advantage over III and IV only for the backgrounds (Letters and Numbers) which are most similar to the targets. This suggests that confusion with the background is reduced somewhat when targets are connected. However, the large difference between patterns I and II suggests that structure, codability or some other factors associated with the row pattern are more critical than connectedness *per se*. For all analyses except Unaided/Position, performance in the Blank condition on II is significantly worse than III or IV. In the absence of background confusion, this difference may well reflect simultaneous masking.

According to Eriksen and Lappin (1967), 1° separation is required for independence of perception. In these matrices, the centers of the element positions are .45° apart, or the separation is about .25°. Considerable interaction is expected, but for the filled background conditions, it will not vary with pattern. Only in the Blank condition is degree of retinal interaction correlated with pattern. Targets are closest together in pattern II (cf. Fig. 1 and Appendix I), so there should be considerable masking and hence depression of performance. The elements in pattern I should mask one another to a slightly lesser extent. Masking should be of almost negligible importance for patterns III and IV; targets are separated by at least .75° and often by more than 1°.

Patterns III and IV differ significantly only with the Blank background under Unaided Recall and Position scoring. It is evidently easier to determine absolute position information for left-right symmetric than for random patterns; the symmetric pattern carries with it information about column placement. The absence of any other significant differences suggests that codability (assuming of course that the symmetric patterns were codable) is of negligible importance compared to the effect of target element separation; only when items are connected is structure important. Subjects' position errors indicate that they did not distinguish patterns III and IV; the elements in pattern III were often misplaced to form symmetric pattern other than the one presented. No such constructions were observed for pattern IV. At the end of the experiment, it was found that Ss could reproduce about half the patterns exemplifying

TABLE 4

SIMPLE MAIN EFFECTS AND ORTHOGONAL CELL COMPARISONS:

F RATIOS FOR BACKGROUND EFFECTS AT EACH LEVEL OF PATTERN

Level of Pattern	Unaided		Aided	
	Free Recall	Correct Position	Free Recall	Correct Position
I	68.1224***	24.9921***	47.8021***	30.9346***
B(S,L,N)	94.7903***	18.1302***	72.6528***	49.4182***
S(L,N)	109.3698***	56.6571***	68.3834***	41.8361***
L,N	.2071	.1889	2.3641	1.5495
II	59.7929***	19.9514***	43.5759***	28.5498***
B(S,L,N)	112.9520***	31.8959***	86.7982***	53.4675***
S(L,N)	55.6888***	21.1589***	38.0356***	23.3394***
L,N	10.7378**	6,7988*	5,8939*	11.9807**
III	12[illegible].34[illegible]3***	30.8842***	108.5043***	80.2758***
B(S,L,N)	261.3003***	34.6247***	227.9529***	156.4221***
S(L,N)	89.4822***	51.7328***	89.0725***	77.8583***
L,N	13.2566***	6.7988*	8.4873**	6.5470*
IV	103.9028***	14.1433***	103.8383***	76.9090***
B(S,L,N)	200.4525***	4.0429*	211.3090***	146.2206***
S(L,N)	98.6541***	34.2741***	92.6354***	74.3752***
L,N	12.6017***	4.1129*	7.5704*	5.5284*

Simple Main Effects, df = (3,54) Cell Comparisons, df = (1,54)
***p < .001 **p < .01 *p < .05

classes II and III, but none for IV.

The effects of Background are more easily described. The main effect of Background is highly significant at all levels of Pattern, but the size of the effect is smallest for the row pattern, and largest for the scattered patterns. The Blank vs. filled, and Squares vs. Letters-Numbers cell comparisons are highly significant at all levels of pattern and for all analyses except Unaided/Position. There is, however, a general trend for the effects to be largest for the more separated patterns. Different results are obtained for Unaided/Position; with Pattern IV, the Blank vs. filled comparison barely approached significance. This reflects S's difficulty in determining the absolute positions of targets in the absence of background filler items. There is a clear trend for the Letters-Numbers comparison. This comparison does not approach significance in the row condition, but is significant at all other levels of Pattern. The size of the effect does not appear to vary among the non-row patterns.

Summary of Results--Thus this experiment shows that the spatial arrangement of the cued elements is a powerful determinant of performance. However, the experiment does not indicate why, in terms of experimental parameters, the patterns differ in their effect on performance. It was initially hoped that this experiment would separate two factors, connectedness and codability, which were hypothesized to be responsible for the effects of pattern. Either this experiment did not provide distinct examples of connectedness and codability, or it is not the case that the intersection of the values of these 2 factors determines the selection efficiency of the pattern. It is quite possible that the difference between row and the other patterns is more complex.

Since S must report 5 letters, he must hold them briefly in verbal short-term memory. Information about the letter identities, the locations of the targets' positions, and the pairing of letter and position must also be encoded for memory. Thus, performance in the partial report paradigm reflects memory processes as well as the more perceptual processes involved in selection from a visual store.

The row condition appears to have a clear advantage for short-term memory position coding. The pattern description is brief, and easily expressed verbally, e.g., "Row 2." The other 3 pattern types are much more difficult to describe and S may waste time formulating longer and less precise descriptions. In addition, there is a simple rule for pairing letter names and row positions. A row label and an ordered list coupled with the usual left-to-right rule should suffice. There is no simple way to express the pairings in the other conditions, and S may be attempting to use a combination of verbal and visual codes. Thus it is possible that the row advantage is primarily due to the STM demands, and would disappear in the absence of memory requirements. This possibility is investigated in the next experiment.

CHAPTER III

EXPERIMENTS II AND III

Introduction

In order to investigate the possibility that short-term memory limitations were partly responsible for the Pattern effect observed in Experiment I, and particularly for the substantial advantage of the row condition, the pattern types were compared in a detection analog of Experiment I. Again, 5 red letters were positioned in a 5 x 5 matrix. Among these was a single target letter, either an A or a T, and S had to indicate which was present; S was not asked to specify position. Thus, there should be no output interference or loss or confusion of items held in short-term memory. Any observed effects should reflect only lower-level processes.

Since the Pattern effect was strongest in the Letters Background Condition, only this condition is tested in Experiments II and III. If a Pattern effect is present when any possible memory confoundings are absent, it is most likely to appear in this condition. Further, the Letters Background Condition should be difficult enough that pattern differences are not masked by a performance ceiling; in a short pilot study, detection performance inthe Blank Background Condition did not vary with pattern, being constant at 100%.

In Experiments II and III, a column pattern was added to those tested in Experiment I. This arrangement shares the connectedness, sample population, dimensionality and codability characteristics of the row pattern, but it does not correspond to left-right reading habits.

Experiment II

Method

Subjects--The subjects were 8 University of Michigan students (3 men, 5 women) who volunteered to serve in paid experiments. Each was paid $6.50 for participating.

Stimulus materials--The stimuli were 5 x 5 matrices of letters, with 5 of the letters in red and 20 in black. Four of the pattern types and the 5 exemplars of each were those used in Exp. I. In addition, a column pattern was included. In a whole-matrix control condition, all 25 positions were filled with red letters. Red and black letters alike were made with Tactype #5518. The spacing of the letters was identical to that in Exp. I.

In order to control for retinal locus of the target in each pattern exemplar, 5 instances of each exemplar were constructed. An A or a T appeared in each instance. Over the 5 instances of each exemplar, A or T appeared as the target in each red position with the constraint that no target be used more than 3 times. For each pattern type, the 2 target letters were used equally often. Over the 25 instances of the all-red condition, A's and T's appeared in alternate matrix cells. Over all 150 items, A and T appeared equally often in each cell.

After the target letter was positioned, the remaining 24 non-target letters were arranged among the rest of the matrix positions. In the pattern conditions, these were assigned with the constraint that over the 125 items, each letter appear in each position 4 or 5 times as a black letter and no more than once as a red letter. In the all red condition, each non-target letter appeared once in each position.

Apparatus--The stimuli were again presented in Field 1 and the fixation dot in Field B of the 3-channel tachistoscope. Luminance levels were 15 and 10 ft.-L respectively. The same square masks were used to frame the display area. The room was dark except for the light used by the Experimenter.

Procedure--The Ss were tested in 3 sessions separated by approximately 24 hours. On Day 1, Ss were shown 5 cards illustrating the 5 pattern types. These cards were used to provide 5 to 10 warm-up trials at the beginning of each session and after each mid-session break. The S was told that he must decide on each trial whether an A or a T was present among the red letters; he was informed that the target would never appear among the black letters. In addition, S was asked to use a 3-point confidence rating scale, with "3" indicating that his choice was mostly a guess.

The pattern cards were divided into 2 decks, with roughly equal numbers of exemplars of each pattern type in each. On each day, one pattern deck was presented first, then the all-red deck, and finally the remaining pattern deck. The order of presentation of the 2 pattern decks and the direction of presentation of the cards within a deck was balanced over subjects. After a short break, the same sequence of decks was presented, with the cards in each deck displayed in reverse order. On each day the cards within each deck were randomized.

On each trial, S initiated stimulus presentation by means of a hand switch, and then reported aloud his choice of target and his confidence rating. The experimenter recorded his responses. For most subjects, each session took just under one hour.

Results

A signal-detection analysis was applied to the confidence-rating data. The 3 confidence levels were taken as successive criterion cuts, and Receiver Operating Characteristics (ROCs) were plotted. Because the ROC curve must be symmetric about the negative diagonal for forced choice data, the area under the ROC curve, A_G, is a more appropriate measure of sensitivity than is d'. The A_G measure is linearly related to the proportion correct and, unlike d', can be averaged over Ss. For these data, A_G was computed on the 50 observations for each S on each day for each selection condition. In the upper panel of Figure 4 are shown the mean A_G values, averaged over 8 Ss, as a function of selection condition and days of practice.

It is apparent from Figure 4 that performance is better in the row condition (pattern Ir) than in any other selection condition. Differences among the cued pattern conditions are unsystematic, and performance on the whole-matrix condition (W) is not obviously worse than any pattern condition except row.

These observations are confirmed by analyses of variance (Days (3) x Selection Conditions (6) x Ss (8)) on arcsin transforms (2 arcsin $\sqrt{p}$) of the A_G scores. The Selection Condition effect was significant ($F_{5,35} = 3.0199$, $p < .025$), and the Days effect highly significant ($F_{2,14} = 9.3283$, $p < .005$). The Selection Condition x Days interaction did not approach significance ($F < 1.00$). This suggests that while Ss were improving at the detection task, this effect was not produced by an increasing use of the subset restriction information provided by the red pattern.

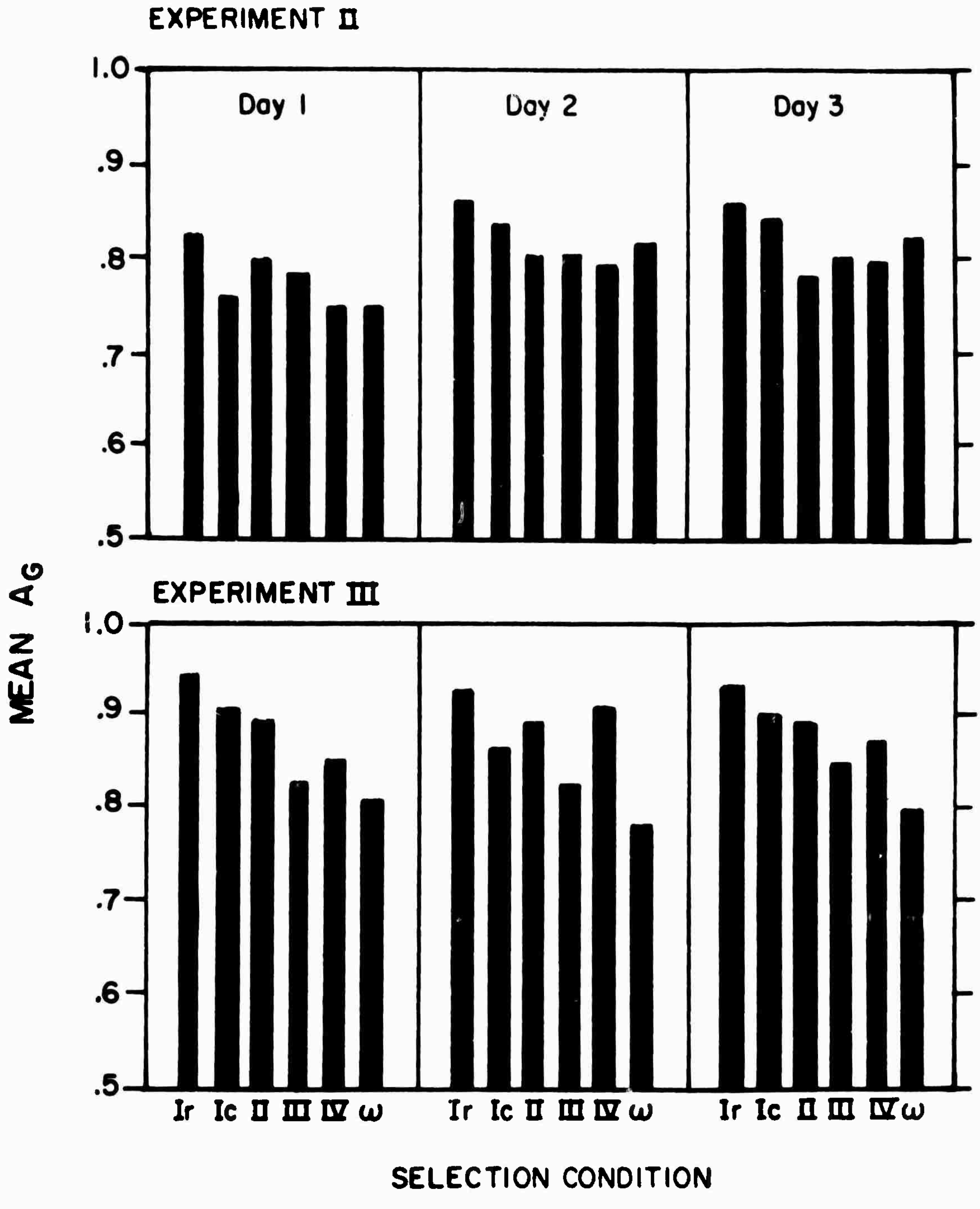

Fig. 4. Mean A_G as a function of selection condition and days of practice for Experiment II (upper panel) and Experiment III (lower panel).

The Selection Conditions main effect was partitioned into 5 orthogonal components: whole matrix vs. patterns, pattern Ir vs. all other patterns; pattern Ic vs. II, III and IV; II vs. III and IV; and III vs. IV. Only the second comparison (row vs. the other patterns) was significant ($F_{1,35} = 11.4812$, $p < .005$).

The data were also analyzed in terms of the proportion of correct responses, ignoring confidence ratings. The findings of an analysis of variance on arcsin transforms of the proportion scores parallel those for the A_G scores. The Selection Condition effect was marginally significant ($F_{5,35} = 2.6904$, $p < .05$), while the Days effect was highly significant ($F_{2,14} = 7.9713$, $p < .005$). The Selection Condition by Day interaction did not approach significance. The same 5 orthogonal components comprising the Selection main effect were tested, and only the row vs. other pattern comparison was significant ($F_{1,35} = 8.3372$, $p < .01$). Thus the only difference between the proportion correct and A_G analyses is the slight increase in the Selection effect with A_G. This reflects the variation in the use of the confidence ratings over the different selection conditions. The 3-rating was used most often in the row condition, and 1's most often in the whole-matrix condition; even when Ss did no worse on the whole condition, they maintained that the task was vastly more difficult. Thus S appears to be shifting his criterion, β, with little accompanying shift in d'. Evidently, a subject's description of his detection performance adds very little to the information provided by the detection rate itself.

It was rather surprising to find that the whole matrix vs. pattern comparison was not significant. Evidently the information provided by the color cue in patterns Ic, II, III and IV was not used. While patterns III and IV did not differ in the Letters background condition in Exp. I (and the partial estimates for these conditions were not much above the level expected for whole report), there was an advantage for pattern II. It might thus be expected that Ss in Exp. II would also have been able to use the information in this condition, and certainly the information in the column condition. Given the low overall level of performance (about 78% correct responses), Ss clearly would have benefited from a greater use of the pattern information.

It is possible that differences in the results of Exp. I and II reflect differences in the partial report and detection paradigms. Before considering this possibility, other non paradigm-specific differences between the two experiments should be examined. First, although Ss in Exp. I had fewer total trials (480) than did Ss in Exp. II (900), Exp. I may have provided more effective practice. In Exp. I, if Ss had not perceived the pattern clearly during presentation, they had several seconds to view the pattern afterward, and could correct or confirm the original impression. Their reproductions of the patterns after the experiment indicated some long term learning of patterns II and III. In Exp. II, position specification was not required, so Ss may have made no attempt to learn the patterns; in addition they had no opportunity to check the accuracy of their memory for the patterns.

It is possible that if Ss cannot picture the patterns, they will have difficulty attending to the appropriate positions during the presentation. This might account, in part, for the clear advantage of row in both experiments; S has a clear picture of the pattern, and may be able to "aim" at the cued items. Further, knowledge of the pattern allows S to take advantage of partial perception of the pattern. For example, if 3 positions in a single row (2 of them adjacent), and none elsewhere, are perceived as red, S may infer that the row was cued, and can profitably process all items in that row. If he sees two colored positions in scattered locations, and has not thoroughly learned the possible patterns, he can make no similar inference about which other positions were cued.

There also seem to be substantial differences in color detection thresholds between the Ss in the 2 experiments. In Exp. I, all 8 Ss distinguished the red color from the black background, and commented that the red pattern stood out, strikingly for all Ss in the connected conditions (I and II), though less so for some Ss in the scattered conditions (III and IV). Since there was no problem with color perception either in Exp. I or in the pilot study for Exp. II, Ss were not screened for color perception. In Exp. II, 5 Ss commented on the clarity of the pattern in the connected conditions.(Ir, Ic, II), but found the color discrimination somewhat more difficult in conditions III and IV. Three Ss (all female) said they had difficulty seeing the red color on the pattern cards on any day, and first perceived the red-black and all-red cards as different on Day 3. Two other Ss began to see color on Day 2, and one said she could see it on most trials on Day 3. It is possible that the absence of a whole-pattern effect in Exp. II is due to combining data from Ss who saw and used color information and those who could not. It is quite possible that Ss in Exp. II had difficulty perceiving the patterns because color alone distinguished the targets; in Exp. I, the targets were somewhat larger as well. This could explain the greater difficulty in Exp. II of seeing patterns III and IV, but it does not explain the inability of some Ss to see the red color at all.

In order to check this possibility, the data were re-analyzed separately for Ss who reported they could (N=5) and Ss who reported they could not (N=3) distinguish the red color. The difference between the 2 groups in overall level of performance is striking: 79% correct responses averaged over the 3 days for color detectors, and 66% for the non color detectors. For the whole matrix condition, performance was 4 to 12 percentage points lower for the non-detectors. Analyses of variance on the arcsin transforms of the proportion correct and A_G scores were performed separately for the 2 groups. For the group who claimed not to see color, there was no effect of Selection Condition under either scoring procedure. There was a slight, but non-significant, effect of Days of practice, with the increase appearing somewhat larger for the A_G scores. For the Ss who claimed to see color, the results are very different. For the proportion scores, the Selection main effect was significant ($F_{5,20} = 3.9051$, $p < .05$), as was the Days effect ($F_{2,8} = 5.9198$, $p < .05$). These factors did not interact. When the same orthogonal comparisons were tested, the whole-pattern component was found to be significant ($F_{1,20} = 5.1461$, $p < .05$). This effect, however, is primarily due to the larger row vs. other pattern comparison ($F_{1,20} = 9.3840$, $p < .01$). No other comparison approached significance. The results for the A_G scores are highly similar.

These results suggest that in a detection task, Ss will make use of color information if they can perceive it, but only in the row condition. This conclusion is weak because the Ss were separated on the basis of their statements about perceiving color. They could equally well have been divided on the basis of other statements. For example, there was a wide variety of opinion about the difficulty of the different patterns, the difference being the whole matrix and pattern conditions, and the relative difficulty of pattern IV and the whole matrix. Some independent measure of ability to use color cues is necessary. Experiment III was performed to see if other patterns would be useful for Ss who had demonstrated an ability to use color cues in different circumstances. This experiment was a replication of Exp. II using 4 of the Ss who had served in Exp. I.

Experiment III

Method

With the following exceptions, all aspects of Exp. III were the same as in Exp. II. The Ss were 4 of the 8 from Exp. I (1 man and 3 women), and the luminance levels in the stimulus and fixation fields were 18 and 8 ft.-L respectively. The interval between Exps. I and III was approximately 1 month. Each S was paid $6.00 for participating.

Results

The main results, for the A_G scores, are shown in the lower panel of Fig. 4. An ANOVA of the transformed scores indicates that the Selection Condition effect is highly significant ($F_{5,15} = 4.8542$, $p < .01$). When the main effect was partitioned, the whole-partial comparison was found to be highly significant ($F_{1,15}$ = 13.7725, $p < .005$), as was the row vs. other patterns. component ($F_{1,15}$ = 6.2741, $p < .025$). No other comparisons reached significance. However, the row vs. patterns component does not appear to account for all of the whole-partial effect; this suggests that Ss are making some use of the other patterns. The effect of days of practice was not significant. The results are similar for proportion correct; Selection Condition was highly significant ($F_{1,15}$ = 5.0921, $p < .01$), and again only the whole vs. pattern ($F_{1,15}$ = 8.2372, $p < .025$) and row vs. other pattern ($F_{1,15}$ = 12,7215, $p < .005$) comparisons were significant.

Although the orderings of conditions Ic, II, III and IV shown in Fig. 4 are not significant, they are fairly consistent (except on Day 2). This contrasts with the finding for the color perceivers in Exp. II; for them row was better than the other 5 conditions which did not appear to differ. This suggests that more patterns might be differentiated after even more practice. However, the absence of a Days effect in Exp. III suggests that improvement will be very gradual.

Experiments II and III thus demonstrate selection in a paradigm in which there is virtually no short-term memory load. Differences in performance between the pattern and whole-matrix conditions do not depend on assumptions about the appropriate scoring method, output interference, or guessing corrections; instead, the whole-partial difference is based on a straightforward comparison of detection accuracy. Accuracy can exceed that of the whole-matrix condition only if S is able to process fewer items, or somehow make more efficient decisions; i.e., he must be able to select.

CHAPTER IV

GENERAL DISCUSSION

These three experiments strongly suggest that Ss are able to select from the short-term visual store, and that the spatial configuration of the cued subset is a powerful determinant of performance. While some of the spatial selection effects found in Experiment I and in previously published research may reflect short-term memory demands peculiar to Partial Report, Experiments II and III indicate that there are substantial effects reflecting processes at a level common to both Detection and Partial Report.

A large amount of empirical observation about the visual store has now accumulated. While more parametric studies of some aspects are needed, it now seems appropriate to work towards a viable model of the processes by which S attempts to report or detect items in the store when he can restrict the set of relevant items on the basis of some selection criterion.

Before considering two current models of visual perception in some detail, the results of the detection and partial report experimemts for each pattern type are briefly reviewed and contrasted below.

Comparisons of Partial Report (Letters Background) and Detection Results

It appears from Experiments I, II, and III that most Ss who are able to detect color during a tachistoscopic exposure can make use of a color cue to restrict the population of items to be considered. The degree of success is strongly dependent upon the spatial configuration of the cued subset, and skill in using the cue increases with practice. While the general ordering of success in using the different patterns (i.e., row best and scattered worst), is the same for Partial Report and Detection, differences among selection conditions are more pronounced for Partial Report.

For both Partial Report and Detection, the row pattern is clearly superior to all other arrangements. Since this is found in the absence of short-term memory coding demands, the row advantage must reflect lower level processes. Some aspect of processing a row has probably been very thoroughly learned through long practice in reading. Perhaps Ss are very adept at serially scanning a line; perhaps they are very well practiced at ignoring items not in the line.

A rather surprising finding in Experiments II and III is the absence of a significant advantage for the column pattern. This pattern shares all the connectedness, structure, dimensionality and codability properties of the row pattern. The difference may be that the normal left to right scanning habit is less appropriate for column than for any other pattern; for all patterns except column, at least two cued items appear in at least 1 row. The substantial row-column difference is also consistent with the findings of Taylor (1970). In a detection paradigm, he had Ss determine whether one or two instances of a target were present. For different groups of Ss, the repeated targets always appeared in either the same row or the same column. Only after three days of practice were Ss in the "vertical" condition as successful as Ss in the more normal "horizontal" condition. Subjects in Experiments II and III also had three days of practice, but had to spend this time learning patterns II, III and IV as well as Ir and Ic.

With the detection procedure, there is no selection effect for Patterns II and IV, although in Experiment III these conditions are consistently, if not significantly, better than the whole-matrix condition. The absence of significant selection effects is consistent with the finding in Experiment I (cf. Letters Background, Figure 3) that an average of only one letter is reported for these conditions. Even if this number is multiplied by the number of equiprobable samples (5), the partial estimate barely exceeds the level expected for whole report. Subjects in Experiment II who claimed to be seeing only the red letters in the row condition commented that it was as difficult to detect the target in conditions II and IV as in the whole-matrix condition; for these three conditions, Ss described "searching all 25 positions instead of just a subset." Some Ss in Experiment II said that detection was actually more difficult with Pattern IV than with the whole matrix: they wasted time finding the red letters instead of searching for the feature(s) that distinguish A and T. The more practiced Ss in Experiment III appeared to be making some slight use of Patterns III and IV, as they did in Experiment I.

In the detection experiments, Pattern II was not reliably more useful than Patterns III and IV, although Figure 4 (lower panel) suggests that practiced Ss began to make use of it. When the effect of Pattern II in the Letters Background condition of Experiment I (cf. Table 3) is considered more closely, the absence of a significant effect in the detection experiments is not too surprising. With free recall scoring, the II vs. III and IV comparison is significant, but accounts for a relatively small proportion of the simple main effect. For position scoring this comparison is not significant.

The results of the detection and partial report (Letters Background) experiments for the different pattern types are thus quite similar. Because no column condition was included in Experiment I, it is not possible to tell whether the poor performance in Detection would also be found in Partial Report. Patterns II, III and IV may be more differentiated in Partial Report because differences in codability appear when short-term memory coding is required. Two other factors may also help to explain the less successful use of Patterns II, III and IV in Detection. First, the discriminability of the patterns differed. Color alone distinguished the targets in Experiments II and III; the absence of the correlated size information may have made the difference between patterns just clear enough and patterns not quite clear enough to be used. Second, while the detection task does not require memory for position, it may have had more stringent spatial demands of another sort. This hypothesis is suggested by the comments of two of the four Ss who served in Experiments I and III. They explained that the detection experiment was easier because of the lessened memory load and the absence of a position specification requirement, but harder in that it was necessary to deal with all of the cued positions. For Partial Report, S could report any of the red letters that he happened to see, while in detection he had to consider all positions to decide which critical letter was present; sampling the cued subset (either deliberately or inadvertently) was less effective.

Models of Partial Report and Cued Detection

As was pointed out in Chapter II, there appear to be two aspects of any display of fixed time and intensity that could logically determine performance: The target and the nontarget (background) items. All three experiments showed that the spatial configuration of the target set was important, and Exp. I showed that the similarity of target and background items was crucial. Since the level of performance was high and relatively invariant with pattern type when there were no background items (cf. Figure 3, Blank Background Condition), it appears that spatial configuration *per se* is not all that important. The more important constraint on performance appears to be the target-background similarity; the arrangement of the targets serves to control the degree of interference from the similar background items. Thus, models of cued visual perception must explain how background interference varies with target pattern.

Judging from Ss' comments, it may be reasonable to start with the premise that S tries to locate the cued positions, and becomes confused by the background items either because he must process them in order to find the targets or because his decisions about which elements are targets are faulty. This point of view is general enough to encompass two rather different ideas about how selection takes place. One says that selection is perceptual and that background interference comes from the inefficient filtering of the items that should not be processed. The other says that all items are processed and background interference reflects inefficient decision-level rejection of nontargets. In either case, the role of pattern is, in a sense, prior to that of background.

It may prove rather difficult to understand why some patterns are used more efficiently than others. The patterns tested in these experiments could be characterized by a number of attributes such as codability, connectedness and dimensionality. It was not clear how much each factor contributed to success in selection. The main predictor of success seemed to be the appropriateness of reading-scanning habits. Thus, characteristics that control selection efficiency must be determined empirically.

Given that S is, at some level, handling background items as he does targets, the ordering of performance for conditions of differing background similarity is not difficult to predict. The four backgrounds tested in Experiment I seemed to fall along a single dimension of number of shared features (light-dark ratio and overall size being held approximately constant). When letters were used in both target and background sets, the level of similarity was very high. The numbers shared features with the target letters, but there were no target and background items that were identical. Squares shared only the features of horizontal and vertical lines and right angles. Thus it seems likely that any model that can explain confusion among attended items and can also explain why background items are processed, can explain the main effect of target-background similarity.

There are two current models of visual perception designed to handle tachistoscopic presentation. The first is the Rumelhart (1970) multicomponent model and the second is Gardner's (1970) Independent Channels-Confusions (ICC) model. These models may be contrasted on a number of characteristics: (a) Rumelhart's model considers selection to be a perceptual level phenomenon; only the selected items are processed to the degree required for response. The ICC model says that all elements are processed and selection comes when S evaluates what he has processed and eliminates some inputs from further consideration by the decision maker. (b) The Rumelhart model assumes limited capacity processing, and the ICC model unlimited capacity. (c) The Rumelhart model was developed to handle partial report, whole report, and whole-matrix detection situations; Gardner's has heretofore been applied only to detection. Both models assume independent processing of the different channel inputs. The two models are described briefly below and modifications necessary for handling the current data are suggested.

Briefly, the Rumelhart model assumes that the display elements are registered in the VIS, and then fade exponentially, becoming gradually less legible. As long as any information is available, a pattern recognizer works to analyze the features in each input channel. There are a number of criterion counters associated with each channel, one for each potential stimulus input. When a feature is extracted in some channel, the counters for each potential input that possesses that feature are incremented (e.g., the analysis of a "short horizontal line" in some channel would increment both the A and T counters). It is assumed that any c features uniquely specify the possible inputs; when the feature count reaches c in some channel, the stimulus can be recognized. Obviously the criterion value must be much higher for letter identification than for detection. An increase in c means that more features must be extracted; there is an attendant decrease in the probability that the defining features will be assumulated before the trace fades. The change in c is the only paramenter change necessary for predicting the results of both partial report and detection experiments; the two situations are considered to be exactly analogous.

The role of similarity among attended items must also be handled by varying c; the value of c increases with increasing similarity. This analysis is reasonable only if S can predict the degree of similarity on each trial and set his criterion accordingly. This may be possible when trials on similarity conditions are blocked, but S should be unable to vary c appropriately with the randomized sequences used in the experiments reported above. This point has been mentioned to Gardner by both Greeno and Shiffrin (Gardner, personal communication). It may be possible to rescue the situation with the aid of some assumptions about how S might shift the value of c during a single trial. For example, if items are very similar, two or more channels might reach c at the same time and output identical decisions about the stimuli in those two channels. The S could adopt the rule that if two channels give identical outputs, he will raise c and continue feature extraction in all attended channels. The implausibility of this modification suggests that it may be very difficult to incorporate similarity in either the original model or any extension which preserves the basic notion of independent recognition and output for the separate channels.

Now consider what happens once the display is registered. The S is assumed to divide his attention (not necessarily equally) among all input channels. When he perceives the cue, S restricts his attention to the cued channels alone, and the background items are no longer functionally present. Since the feature extraction process is assumed to be limited in capacity, the more channels that have to be processed, the slower the rate of feature extraction in each and the less the liklihood that the criterion will be met (and consequently a correct response made) before the image fades beyond usefulness. Clearly, subset restriction according to some selection criterion is predicted to be advantageous. However, it should be noted that only the number of relevant channels matters; there is no way to predict variation in performance when some constant number of cued elements (5 in all the experiments reported above) are arranged in different spatial configurations. This is a major deficiency in the model.

Rumelhart also does not explain how S goes about locating the cued items. In a discussion of Sperling's row cue experiment, he says that S "immediately assigns weights of zero to all but the indicated row of the matrix (1960, p.196)." That is, target choice is perfectly accurate, and presumably involves no processing of background items. With these assumptions, the Rumelhart model cannot predict variation in performance as a function of target-background similarity. This, then, is the second major point at which the model breaks down in handling the data reported above. It is necessary to modify the model to handle both the spatial configuration of the target elements and the confusions with background; it is also necessary to explain why the degree of interference from the background varies with target arrangement.

In attempting to extend the model, it seems most profitable to begin with the target-set selection stage. This phase is ambiguous in the basic model and there are a number of plausible directions for modification. As a first step, it seems necessary to assume that S locates the target set by analyzing all input channels in order to determine which ones have the appropriate value (e.g., middle row, red color) on the selection dimension. In the row cue experiment, the figure-ground differentiation required for row discrimination may be so easy as to be practically "immediate." The color selection task may demand more extensive processing of the display; selection must be "mediate." It must be assumed that processing of dimensions such as color takes time. This assumption of criterial dimension processing is not a departure from the basic model; rather it is an elaboration of a point which seems to have been implicit in the model.

While the assumption of selection dimension processing alone can explain differences in performance with different selection criteria (e.g., row, color, or brightness cues), it cannot explain differences due to variations in the spatial arrangement of items cued by a single selection criterion. In order to explain these spatial effects, it seems necessary to bring in some ad hoc assumptions about target-set pattern differences. One possibility is suggested by Ss' comments about color discriminability. They reported that the red and black colors were most discriminable with the connected target sets, and most similar with the scattered sets. If Rumelhart's model can handle similarity and if the red and black actually function as "similar" with the scattered patterns, then an analogy may be drawn between feature extraction with similar stimuli in all attended channels (as described in the basic model) and color extraction for "similar" colors. In some sense, c for color processing must be raised for the scattered sets. This similarity analysis thus predicts a main effect of pattern, with performance better on connected than on scattered sets. This notion obviously cannot account for all the effects of spatial configuration; substantial differences among row, column and patch patterns were obtained in the above experiments. The model's assumptions about unequal attentional weights for different input channels might be useful here. Perhaps weights could be assigned to combinations of channels. For example, S's preference for reporting a row in whole report suggests that if he decides to attend to any items in one row, all the items in that row must be more closely attended. Since independence of feature extraction is the only independence assumption built into the formal model, it should be possible to incorporate assumptions about dependence in the allotment of attention without violating the spirit of the model.

Given that the effects of similarity among attended items can be predicted, it will be possible to explain background effects if the model can explain why background items are processed. Modification of two other aspects of target selection may enable the model to explain such background processing. The two aspects or stages of processing are the events prior to and the events following target-set choice. These two stages will be referred to as the target search and target acceptance stages. For each of these time periods, there seem to be at least two options for describing the processing in which S engages: While searching for the targets, S may either process only the criterial dimension, or he may also be extracting features from all channels; once S has decided upon a set of target items, he may be attending to the targets alone, or he may have erroneously accepted (and be processing) background items (either in place of or in addition to the targets). Imperfect target acceptance could be modelled as either complete acceptance of and maximal attention to background items, or as imperfect attenuation of background items. The original model is quite clear in rejecting the possibility that nontargets are accepted, so any assumption of mistakes is a departure from the model. The model says nothing about whether or not feature extraction occurs during target search. However, Rumelhart's explanation of processing in a cue-delay experiment suggests an answer: Before the cue, S extracts features from all channels; he narrows his attention only after perception of the cue. It is not unlikely that with the simultaneous cues used in the current experiments, S begins feature extraction of all channels and ceases processing some only when he processes the criterial dimension and determines which channels are relevant. In the original model, feature extraction sounds automatic for all attended channels; it may be harder to explain why S does not process features during some particular time period than why he does. The factorial combination of the two options during target search and the two options following target acceptance yields four distince versions of a modified Rumelhart model.

(a) Criterial dimension processing only plus perfect target selection: There is no possible way of predicting any interference from the background since no features are processed in background channels either during target search or after target acceptance.

(b) Criterial dimension processing only plus imperfect target selection: If no assumptions about similarity are made, this version predicts performance to be worse in the filled background conditions (Letters, Numbers, and Squares) then in the Blank condition. If background items are accepted in addition to the targets, then attention is spread more thinly, and it should take longer for the feature extraction process to reach the criterion for identification or detection. If backgrounds are accepted instead of targets, then each target gets as much attention as it would with perfect target acceptance; however for partial report fewer targets could be reported, and for detection, there is a reduced chance that the critical letter is accepted. Differences among these three background conditions can be explained only if similarity effects can be explained. One option is the repeated criterion shift idea suggested above. Another is the possibility that as soon as c is reached in some channel, all the attention allotted to that channel is re-distributed among the channels that have not yet reached criterion. The Squares are identified with relatively few features, so S could shift attention to the target letters relatively quickly. A later shift might occur with the Numbers backgrounds, and no shift at all with the Letters backgrounds. This, again, is a rather implausible explanation. The Pattern x Background interaction can be explained if it is also clear why more background items are accepted with scattered patterns.

(c) Feature processing plus perfect target selection: Background interference can be explained only if there is some way for the processing of background items prior to the cue to influence performance. The original model says that S is accumulating features in all channels prior to the cue. It is implied that feature accumulation continues in the target channels and stops in the background channels. Since response is based on the output of the attended channels, any prior processing of the background channels should be irrelevant. Given these assumptions, this version of the Rumelhart model cannot predict a Background main effect. A cue-delay extension of Experiment I could be used to assess the possibility that the processing of background items prior to the cue is important. A finding of a progressively larger effect with increasing cue delay would tend to support the idea of feature processing prior to the cue as an important determinant of performance, but would not rule out the possibility that some backgrounds are accepted as targets. A finding of no interaction between cue delay and background could be interpreted in at least two ways: First, it could mean that there is no processing prior to the cue. Second, it could mean that all background processing occurs very rapidly, in the time taken to process a simultaneous cue, and all other delays before target acceptance are irrelevant. Both the second possible finding and the two interpretations are unreasonable.

(d) Feature processing plus imperfect target selection: This version appears to be the most reasonable. The effect of background can be handled without assuming that all background processing occurs during the brief target search stage. Early feature processing is presumably taking place, and the results of the cue-delay experiment would show whether mechanisms by which this processing affects performance must also be included. Again the Pattern x Background interaction can be explained only with auxiliary assumptions about the differential liklihood of accepting background items with the different patterns.

It appears that the Rumelhart model can explain the above data only if a number of new assumptions are made. The assumption of perfect target acceptance must be revised. The restriction of attention in a cueing experiment is most probably approximate rather than precise. This idea is supported by an analysis of intrusions in the Letters Background Condition of Experiment I. Most intrusions came from positions close to those cued; S appeared to be restricting his attention to general areas of the display rather than to precise positions. The Pattern x Background interaction is more easily explained with this assumption. A restriction of attention to "all items in this general area" should result in few nontarget acceptances for row arrangements, and many for scattered arrangements. This assumption, which is really a relaxation of an overly strict assumption in the original model, thus goes a long way towards explaining the main effect of Pattern, and setting the stage for the main effect of Background and the Pattern x Background interaction. Such assumptions about a lack of independence in the allotment of attention to different channels might be incorporated in the original model since the central assumption of independent feature extraction is unchanged. Extensive modification of the mechanisms for handling similarity is also needed. These modifications may involve major changes in the logic of the model. The relevance of feature analysis of background items prior to cue perception still requires investigation. It may be possible to preserve the salient characteristics of the model, namely perceptual-level selection and a change in the distribution of limited capacity attention after cue perception, but the revised model will be rather different from the current one.

In contrast to the Rumelhart model, the ICC model is less a mathematical model than a verbal explanation and a point of view. Consequently it is more difficult to pinpoint its predictions or explain how parameters must be added or modified. Basically the model states that in detection procedures, all channels are processed. The S must then sift these inputs to determine whether the feature(s) identifying A or T were present among the mass of inputs. The more similar the inputs, the greater the chance of an incorrect decision. Since processing capacity is unlimited, the number of elements in the display is irrelevant; it is as easy to apply the tests for A and T to 25 channels as to 5. This conception clearly implies that in a cued-detection experiment, the subset restriction advantage does not come from restricting the set of items that are processed. Rather the advantage comes from restricting the number of processed inputs that the decision maker must consider. According to Gardner (personal communication) there is no need to postulate a capacity limit in the decision phase either; given perceptual confusions, S would make some incorrect decisions even with unlimited time.

It should be noted that the decision making in the ICC model and the criterion count in Rumelhart's model are both Pandemonium-type (Selfridge, 1959) conceptions. However, in the Rumelhart model there is assumed to be a limit on the number of "perceptual demon" inputs, while there is assumed to be no limit in the ICC model.

The evidence in support of the two main provisions of the ICC model, unlimited capacity and errors due to decision-level confusion, comes from a series of experiments by Gardner and Shiffrin. Gardner (1970, 1971) found that when nontargets were not confusable with targets, there was no effect of the number of display items. When nontargets were confusable, there was a systematic effect of display size. This suggests that capacity for processing all input channels is unlimited and confusability alone is important. Shiffrin and Gardner (1971) used stimulus arrays in which four letters, one target and three distractors, appeared in the four corners of an imaginary square. In the simultaneous condition, the four letters were presented together for 50 msec. In the sequential condition, the four letters were presented one at a time, each for 50 msec, in clockwise order. Thus, in both conditions, the target was shown for 50 msec. It might be expected that the amount of attention S had available during 50 msec would be divided among four items in the simultaneous condition, but concentrated on one item during sequential presentation. However, there was found to be no difference in detection accuracy between the two conditions. This strong support for unlimited capacity processing is a clear challenge to the Rumelhart model.

The ICC model can readily handle the cued detection data (Experiments II and III) if appropriate assumptions are made about why it is easier to reject non-row items than irrelevant items in other pattern conditions, i.e., why the "exclusion rules" are more efficient for some patterns. One possible explanation focuses on the required precision of different exclusion rules. More error can be tolerated with some patterns. Exclusion of inputs "not in this general area" is a good rule for dealing with row, column, or patch patterns, since few nontargets would be accepted. It is a poor rule for dealing with scattered patterns because almost as many nontargets as targets would be accepted. (This modification is quite similar to the "imprecise target accpptance" modification suggested for the Rumelhart model.) This explanation tends to favor the pattern attribute of connectedness rather than codability as the prime determinant of performance. It is suggestive that in all three experiments, symmetric scattered patterns were no improvement over random ones. Assuming that some exclusion rule explanation accounts for the differential acceptance of nontargets with different patterns, then both a background main effect and a pattern by background interaction would be predicted in a straightforward fashion.

An to Partial Report appears more difficult. The ICC model would say that all elements are processed to the degree necessary for identification, and then the decision maker decides which are targets and hence should be loaded into short-term memory. There are two problems with this extension. First is the analogy between Detection and Partial Report, and second is the issue of unlimited capacity at the stage of item identification.

The decision in Partial Report about which item(s) to output is not analogous to the decision made in Detection. In Detection, the decision maker decides whether the bulk of the evidence favors A or T. There is no simple way to extend this liklihood ratio decision rule to Partial Report. Without such a decision rule, there are problems in explaining background interference. Assume that S decides which are targets and proceeds to load these items into memory; at some level these items must be checked for plausibility because S never inadvertently reports a Number or Square in place of a target letter. Interference from the Letters Background can be predicted since all items are plausible responses and S has no check on the accuracy of his target choices. However, the difference between Numbers and Squares is not predicted; in either case S supresses these background item responses and is left with only the targets that he accepted as targets. These background conditions are differentiated only with the aid of some additional assumptions. For example, if Squares are identified quickly, S could go back to the icon for another sample of possible target items. (This idea is similar to the redistribution of attention modification suggested for the Rumelhart model.) Thus it appears that the decision-confusion aspect of the ICC model is not applicable to Partial Report. In this case, it may not make much sense to say that a single model is being applied to the two tasks.

While there is no evidence that specifically shows that capacity is limited at the identification stage, such an assumption is consistent with most prior observation, intuition and theorizing. Partial Report has often been assumed to work (cf. von Wright, 1968, 1970) because S need apply the complicated and time-consuming identification analyses to the "correct" items only. Identification has generally been assumed to be serial. For example, Welford, Wessel and Estes (1968) suggest that detection is carried out in parallel, but identification serially. Also, subjects typically claim that they do not see items in the nontarget set. Von Wright (1970) reports experiments in which Ss were found to have no retention of nontarget items, and to do no better on targets that had previously served as nontargets on many previous trials. Of course, the absence of a long-term memory effect does not deny the possibility of processing that is never registered in short-term memory. While there is strong evidence for unlimited capacity processing for detection, it is a big step to infer a similar absence of limitation for identification. Thus, part of the feeling of unreasonableness about any extended ICC model stems from the assumption of unlimited capacity for identification. There is surely a limit to the capacity of short-term memory, but where the transition from unlimited capacity occurs is not at all clear. This point must be investigated before it is possible to tell whether a model sharing the unlimited capacity assumption of the ICC model can be safely extended to partial report experiments.

Several summary comments may be made about the ICC and Rumelhart models. First, the Rumelhart model has the virtue of explaining Partial Report and Detection within a single framework. Since the effect of Pattern was highly similar in the two paradigms, and since it is likely that similar background effects would be found, it appears that the two tasks tap rather similar processes. Second, the suggested modifications make the models more similar to one another. For example, analogous modifications about imprecise target acceptance were made. If enough such modifications are made, these models may make identical predictions, and attempts to distinguish them experimentally may be very difficult. Third, even after modifications it may be possible (at least for Detection) to preserve the salient assumptions for the two models: Limited capacity plus perceptual level selection for the Rumelhart model and unlimited capacity plus decision-level selection for the ICC model. In this sense, two viable models would remain, but their details and many machanisms would be very different from those postulated in the current versions of these model.

APPENDIX A

CENTROID (C), SQUARED DEVIATION FROM CENTROID (Dc), AND SQUARED DEVIATION FROM FIXATION POINT (Df) FOR THE FIVE EXEMPLARS OF EACH PATTERN TYPE

		Pattern Type			
Exemplar		I	II	III	IV
	C	(0,2)	(-1,-1.2)	(0,-.4)	(.4,-.6)
1	Dc	10	4.80	26.04	16.40
	Df	30	17.00	28.00	19.00
	C	(0,1)	(-1.8,.8)	(0,.2)	(.2,-.6)
2	Dc	10	7.60	14.80	22.00
	Df	15	27.00	35.00	19.00
	C	(0,0)	(.4,1.6)	(0,-.2)	(-.2,.4)
3	Dc	10	6.40	14.80	18.00
	Df	10	20.00	15.00	19.00
	C	(0,-1)	(.6,-1)	(0,0)	(-.4,0)
4	Dc	10	5.20	20.00	17.20
	Df	15	12.00	20.00	18.00
	C	(0,-2)	(1.8,-.2)	(0,.4)	(0,.8)
5	Dc	10	7.60	21.20	16.00
	Df	30	24.00	22.00	20.00

Note: Fixation point is (0,0)

APPENDIX B

PATTERN BACKGROUND SUMMARY TABLES FOR EXPERIMENT I

SHOWING MEAN NUMBER OF LETTERS (5 MAXIMUM) REPORTED

Unaided/Free

	I	II	III	IV
L	2.16	1.39	1.09	1.10
M	2.22	1.84	1.59	1.59
S	3.44	2.50	2.46	2.52
B	3.70	3.10	3.52	3.32

Unaided/Position

	I	II	III	IV
L	1.76	.92	.66	.61
M	1.69	1.38	1.11	.96
S	2.85	1.84	1.96	1.66
B	2.70	2.18	2.07	1.36

Aided/Free

	I	II	III	IV
L	2.32	1.48	1.06	1.04
M	2.56	1.85	1.51	1.46
S	3.55	2.49	2.55	2.54
B	3.89	3.11	3.61	3.51

Aided/Position

	I	II	III	IV
L	2.00	1.03	.86	.84
M	2.22	1.56	1.33	1.26
S	3.13	2.05	2.48	2.40
B	3.49	2.63	3.40	3.31

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